Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Connect America Fund	)	WC Docket No. 10-90
	)	
A National Broadband Plan for Our Future	)	GN Docket No. 09-51
	)	
Establishing Just and Reasonable Rates for Local Exchange Carriers	)	WC Docket No. 07-135
	)	
	)	
High-Cost Universal Service Support	)	WC Docket No. 05-337
	)	
Developing an Unified Intercarrier Compensation Regime	)	CC Docket No. 01-92
	)	
	)	
Federal-State Joint Board on Universal Service	)	CC Docket No. 96-45
	)	
Lifeline and Link-Up	)	WC Docket No. 03-109

COMMENTS of ADTRAN, Inc.

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SUMMARY

ADTRAN supports the Commission's goals in this proceeding of revising and modernizing its subsidy and intercarrier compensation regulations to account for changes in technology, increases in competition and the growing importance of broadband services. ADTRAN agrees that the Commission should change the high cost funding mechanism to support the deployment of broadband services to unserved areas, with voice as one application for that service. ADTRAN also concurs in the Commission's proposal to eliminate duplicative and inefficient subsidies.

In addition, ADTRAN strongly supports the Commission's goal of technology neutral rules. ADTRAN believes the Commission can best accomplish this goal by basing the requirements on how broadband services are used, with emphasis on the requirements associated with classes of broadband applications utilized and the traffic volumes generated by such uses. Taking these factors into account, ADTRAN recommends target subsidized broadband rates of 4 Mbps in the downlink direction and 768 kbps in the uplink direction. These rates enable all of the widely used classes of broadband applications, while maximizing the benefit of limited subsidy funding across as many consumers as possible. ADTRAN also recommends a number of additional characteristics with regard to the regulations governing subsidized deployments:

- Rates should be defined and measured at the transport layer.
- Performance should be sustainable. It should support a continuous stream of traffic at the target rate.
- Performance should be reliable. It should meet or exceed the target rate a high percentage of the time when measured during the busy hour.

- One-way latency (excluding jitter) should be no more than 50 ms.

- Limitations (if any) on traffic volume should be appropriate for the type of service. Any limitations on volume should not affect more than a small percentage of the users of a given service

In addition to the service characteristics identified above, the following pre- and post-deployment steps will help ensure the performance of funded broadband deployments.

- Applications for funding should include evidence that planned networks will support the required performance targets through the agreed period of performance, given projected traffic volumes for the service. Evidence could be in the form of transparent/reproducible simulation results or analyses.

- There must be a process for verifying performance post-deployment. The verification process should be periodic, since performance changes over time as subscribers are added, average traffic volume grows and networks are upgraded. Since the Commission, industry, academia, and other groups have been addressing issues related to performance measurement for the past year in the FCC's Broadband Performance Measurement project, many of the details associated with performance verification may be best defined within that effort.

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COMMENTS of ADTRAN, Inc.

ADTRAN, Inc. ("ADTRAN") files these comments in response to the Commission's proposals to modify its high cost, universal support and intercarrier compensation rules to account for changes in technology and policies as broadband becomes ever more important.[1] ADTRAN commends the Commission for initiating these phased, comprehensive steps to resolve the longstanding issues related to various subsidy programs, particularly as IP-based services replace the circuit-switched technologies on which the old rules were based. While the

1 *Connect America Fund*, Notice of Proposed Rulemaking and Further Notice of Proposed Rulemaking (NPRM) in WC Docket No. 10–90, GN Docket No. 09–51, WC Docket No. 07–135, WC Docket No. 05–337, CC Docket No. 01–92, CC Docket No. 96–45, and WC Docket No. 03–109, FCC 11–13, adopted February 8, 2011, and released February 9, 2011 (76 Federal Register 11632, March 2, 2011)(hereafter cited as "*Connect America Fund NPRM*").

Commission's goals are laudable, the "devil is in the details." As explained below, the Commission must ensure that its new rules are efficient, technology neutral and forward looking.

ADTRAN, founded in 1986 and headquartered in Huntsville, Alabama, is a leading global manufacturer of networking and communications equipment, with an innovative portfolio of more than 1,700 solutions for use in the last mile of today's telecommunications networks. ADTRAN's equipment is deployed by some of the world's largest service providers, as well as distributed enterprises and small and medium businesses. Importantly for purposes of this proceeding, ADTRAN solutions enable voice, data, video and Internet communications across copper, fiber and wireless network infrastructures. ADTRAN thus brings an expansive perspective to this proceeding, as well as an understanding of the impact of regulation on network operators' investment decisions.

I. ADTRAN SUPPORTS THE COMMISSION'S GOALS IN THIS PROCEEDING

The Commission has been grappling with the complex issues of subsidization and intercarrier compensation as far back as the late 1970's when competition was first being introduced into the interexchange market.[2] The traditional policy of allowing long distance rates to bear a disproportionate share of costs in order to keep local service rates low helped the goal of universal service, but such hidden (and disproportionately-borne) subsidies are not sustainable in a competitive marketplace. Congress acknowledged this problem when it sought to introduce local services competition in the 1996 Act. Section 254(b)(4)of the 1996 Act, one of the Universal Service Principles, directs that "[a]ll providers of telecommunications services should

[2] *See MTS and WATS Market Structure*, Notice of Inquiry and Proposed Rulemaking, CC Docket No. 78-72, 67 FCC 2d 757 (1978).

make an equitable and nondiscriminatory contribution to the preservation and advancement of universal service."

Congress in Section 254 also gave the Commission broad authority to determine what services should be supported by the universal service subsidy program, including the directive in Section 254(b)(2) that "[a]ccess to advanced telecommunications and information services should be provided in all regions of the Nation." The *Connect America Fund NPRM* seeks to address universal service and intercarrier compensation issues on a comprehensive basis, consistent with the Congressional goals and the Commission's broad powers embodied in the 1996 Act. ADTRAN supports the principles proposed in the *Connect America Fund NPRM,* because if properly implemented, they will well serve the public interest.

The Commission's proposals are driven by the need to revise its regulations to account for the significant changes in technology that have emerged as the telecommunications networks evolve from a circuit-switched, voice-centric technology to IP-based broadband capabilities with voice being one of many applications. The newer broadband services are more efficient and more robust, with significantly greater capabilities, than the circuit-switched technologies they are replacing. ADTRAN agrees that it certainly makes no sense to keep in place a subsidy system that discourages the deployment of newer, better networks.[3] ADTRAN thus supports the Commission's goal of reforming the universal service and high cost subsidy programs to foster the more rapid upgrades to telecommunications networks based on IP-packet technologies.

Moreover, as the National Broadband Plan demonstrates, broadband is growing increasingly important for business, communications, health care, job searches, smart energy

[3] *E.g., Connect America Fund NPRM* at ¶ 506.

grids and education. And while broadband has already been deployed in much of America,[4] there are still areas where the high cost of deployment will preclude broadband without subsidization. ADTRAN thus also endorses the Commission's proposal to transform the existing high-cost USF program into a new, more efficient, broadband-focused "Connect America Fund."

The *Connect America Fund NPRM* also recognizes we cannot afford a subsidy program that is wasteful or duplicative. The necessary subsidies for deploying broadband to presently unserved areas will be very expensive – according to the FCC Model developed in connection with the National Broadband Plan, the costs for subsidizing deployment of broadband networks to these unserved areas could range from $24.5 Billion to $62.1 Billion,[5] depending on the technologies used and the capabilities provided. There is also likely to be a need for ongoing subsidization of broadband services in high cost areas in order to make service affordable. The economics of these unserved areas are such that no entry has occurred to date without subsidization. Thus, while there may be benefits from the competition that arises when multiple providers are offering service, clearly the costs of subsidizing deployment would soar if several providers were being subsidized in each territory. Moreover, any such competition would be "synthetic," since the entry costs have deterred any broadband providers, much less multiple providers, and any such managed "synthetic competition" is costly and does not produce the benefits of real competition.[6] Thus, ADTRAN supports the Commission's proposal to end the

[4] According to the National Broadband Plan, 95% of the U.S. population live in housing units with access to terrestrial, fixed broadband infrastructure capable of supporting actual download speeds of at least 4 Mbps. *National Broadband Plan* at p. 20.

[5] "The Broadband Availability Gap," OBI Technical Paper No. 1 at pp. 1 and 96.

[6] *United States Telecom Ass'n v. FCC*, 359 F.3d 554, 573 (D.C. Cir. 2004), *cert. denied*, 125 S.Ct. 313, 316, 345 (2004).

current practice of subsidizing multiple competitors as is done with the high-cost fund for voice services today.[7]

On the other hand, ADTRAN recognizes that there are important differences between fixed and mobile broadband services, and that each offers tremendous benefits that cannot reliably be fulfilled by the other. Mobile broadband services meet the need for broadband access as the customer moves from location to location (and while in motion). For some applications, such as remote monitoring of a patient's condition in an ambulance, continuous broadband service can literally mean the difference between life and death. In contrast, for many other applications where network capacity and reliability are critical, only fixed broadband services will suffice. While ADTRAN opposes duplicative subsidies, ADTRAN does support the *Connect America Fund NPRM*'s alternative proposal to subsidize both a fixed and a mobile broadband provider in each presently unserved market.[8]

In many respects, fixed and mobile broadband are complementary, not duplicative. Obviously, mobile broadband services support mobility. Less obviously, but just as important, fixed broadband services support traffic volumes that are at least an order of magnitude higher than those supported by mobile services. According to Cisco, in 2010 fixed broadband connections generated on average 14.9 GBytes per month in traffic, whereas laptops – the mobile device type using the highest volume – generated only 1.7 GBytes per month.[9]

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[7] *Connect America Fund NPRM* at ¶ 281.

[8] *Connect America Fund NPRM* at ¶ 403.

[9] Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010-2015," February 1, 2011; Cisco, "Cisco Visual Networking Index: Usage," October 25, 2010.

Just as mobile broadband service requirements cannot be met with implementations that do not support mobility, fixed broadband service requirements cannot be met with implementations that do not provide sufficient capacity to handle the volumes associated with fixed service. Requirements for subsidized broadband services must reflect these distinctions – otherwise, actual performance in subsidized broadband deployments will not meet targeted needs and expectations.

As the *Connect America Fund NPRM* recognizes, moreover, the subsidy program could affect competition between different providers of broadband service, as well as different technologies used to provide broadband service. As a telecom equipment manufacturer, ADTRAN is particularly sensitive to regulators intentionally or inadvertently placing their thumbs on the scales of competition. The Commission certainly asserts in the *Connect America Fund NPRM* its intent to be "technology neutral":

- *Connect America Fund NPRM* at ¶ 82: "We believe our proposal to support broadband is competitively neutral because it will not unfairly advantage one provider over another or one technology over another. We invite comment on whether our proposals are technology neutral. We also seek comment on whether our proposed reforms are consistent with the directive in section 254(b)(5) that support 'should be specific, predictable, and sufficient.'"
- *Connect America Fund NPRM* at ¶ 104: "First, we propose to characterize broadband without reference to any particular technology, so that current high-cost and future CAF recipients would be permitted to use any technology platform, or combination of technology platforms, that satisfies the specified metrics. We envision that recipients will choose a range of technologies, including wireline technologies, fixed and mobile terrestrial wireless technologies, and fixed and mobile satellite technologies in any combination. Although this proposal would not require that recipients employ any particular type of technology, we seek comment on whether there are reasons to adopt technology-specific minimum standards that would depend on the technology deployed, given that there are trade-offs among the different types of technologies. For instance, should specific but not identical standards be adopted

for wireline versus wireless, fixed versus mobile, or terrestrial versus satellite technologies, given the attributes and challenges of these different networks?"

- *Connect America Fund NPRM* at ¶ 284: "It will also allow us to select providers without regard to the type of technology used by such providers, consistent with our goal of being technology-neutral."
- *Connect America Fund NPRM* at ¶ 418: "Any carrier that plans to use technology that can meet or exceed the proposed performance requirements and accepts the associated public interest obligations would be eligible for support. Ultimately, the carrier would decide what technology or combination of technologies is most appropriate to serve its own territory. In addition, the process could be designed in a way that allows a carrier to use technologies that may not meet the minimum performance requirements in place at that time, such as satellite technologies, for the most costly housing units to serve, in order to manage the overall size of the Fund."
- *Connect America Fund NPRM* at ¶ 445: "The geographic areas where the right of first refusal is offered would necessarily be defined by the [Carrier of Last Resorts'] service areas. Despite this constraint, the areas for auction should be defined in as technology neutral a way as possible."

The Commission, however, must not merely preach "technology neutrality," but must adopt technical requirements (including measurement techniques and standards) that do not unfairly favor any particular technology. The requirements should be both service-specific (*i.e.,* mobile and fixed broadband) and technology-neutral. That is, fixed and mobile broadband services can be specified with legitimately different requirements. However, the requirements for a given service must be met without any special consideration for the type of access technology used to provide that service.

As explained in greater detail below in response to specific questions posed in the *Connect America Fund NPRM,* this can best be accomplished by basing the requirements on how broadband services are used, with emphasis on the requirements associated with classes of broadband applications utilized and the traffic volumes generated by such uses. Taking these factors into account, ADTRAN recommends target broadband rates of 4 Mbps in the downlink direction and 768 kbps in the uplink direction. These rates enable all of the widely used classes of broadband applications, while maximizing the benefit of limited subsidy funding across as many consumers as possible. ADTRAN also recommends a number of additional characteristics with regard to the regulations governing subsidized deployments:

- Rates should be defined and measured at the transport layer.
- Performance should be sustainable. It should support a continuous stream of traffic at the target rate.
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In addition to the service characteristics identified above, the following pre- and post-deployment steps will help ensure the performance of funded broadband deployments.

- Applications for funding should include evidence that planned networks will support the required performance targets through the agreed period of performance, given projected traffic volumes for the service. Evidence could be in the form of transparent/reproducible simulation results or analyses.
- There must be a process for verifying performance post-deployment. The verification process should be periodic, since performance changes over time as subscribers are added, average traffic volume grows and networks are upgraded. Since the Commission, industry, academia, and other groups have been addressing issues related to performance measurement for the past year in the FCC's Broadband Performance Measurement project, many of the details associated with performance verification may best be defined within that effort.

The following comments are aligned with the paragraph numbering in the *Connect America Fund NPRM*. Since the same topics are addressed in multiple places in *Connect America Fund NPRM*, these comments may be applicable to other paragraphs as well.

II. RESPONSE TO SPECIFIC QUESTIONS RAISED IN THE *CONNECT AMERICA FUND NPRM*

A. Fixed vs. Mobile Services and Technology Independence

Connect America Fund NPRM ¶ 104:

ADTRAN strongly supports the Commission's proposal to "characterize broadband without reference to any particular technology." Further, we urge the Commission to avoid adopting any "technology-specific minimum standards" that would introduce technology-based prejudice into the requirements or selection criteria for a given broadband service. Any such technology-specific standards would tend to bias the selection process towards the lowest performing technology and would effectively limit performance for subsidized broadband services to the lowest common denominator. Since in a reverse auction – as contemplated in the *Connect America Fund NPRM* – the winning bid can frequently be just slightly lower than the second least costly bid incorporating a more robust technology,[10] a failure to adopt appropriate standards would also result in less cost-effective funding.

Even seemingly technology-independent requirements can bias the process unfairly towards a lower-performing technology if the requirements are not well suited to the service for which they are intended. For example, the traffic volumes projected over the defined period for

[10] "The Broadband Availability Gap," OBI Technical Paper No. 1 at p. 39.

funding must realistically reflect the best estimates available for the type of broadband service under consideration. In particular, fixed broadband subscribers generate dramatically higher traffic volumes than do mobile broadband subscribers. According to Cisco, the average smartphone generated 79 MB of traffic per month and the average mobile laptop user generated 1.7 GB per month in 2010.[11] Compare this with the average fixed broadband connection, which according to Cisco generated 14.9 GB of traffic per month in 2010[12] – nearly an order of magnitude higher than the most traffic-hungry class of mobile devices. This disparity between fixed and mobile usage is understandable given that fixed broadband connections are used to connect entire home networks to the Internet. These home networks consist of multiple devices including large screen televisions over which streaming video may be displayed, as well as multiple devices generating traffic in parallel. On the other hand, mobile connections are generally limited to a single device with a laptop or smaller size screen.

There is a strong relationship between the amount of traffic generated by a pool of broadband subscribers, the amount of network capacity allocated to those subscribers, and the resulting broadband performance. If, for example, recipients are awarded funding based on traffic projections which are substantially lower than realistic estimates, the process may be biased towards technologies for which lower costs of deployment are strongly tied to lower shared network capacity. When the networks are deployed and consumers attempt to generate traffic volumes commensurate with desired services, the resulting performance will be substantially worse than expected. The cost to correct such performance shortfalls can easily

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11 Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010-2015," February 1, 2011, p. 2.

12 Cisco, "Cisco Visual Networking Index: Usage," October 25, 2010, p. 1.

exceed the cost of awarding funding had it been based on well designed requirements to begin with.

***Connect America Fund NPRM* ¶ 114**

The volume of traffic generated by different types of broadband services is a critical factor in evaluating the performance potential of the solutions proposed to provide those services. As discussed in the responses to the questions raised in paragraph 104, the average volume generated per connection by fixed broadband services exceeds that of mobile services by an order of magnitude. There is a strong relationship between the volume of traffic generated by a pool of broadband subscribers, the shared capacity of the network serving those subscribers, and the resulting broadband performance. For a network of a given capacity, as the total traffic volume increases, the broadband performance experienced by the individual users served by that network decreases. Expressed differently, a network needs greater capacity to serve greater traffic volume at the same level of performance. Because of this, fixed and mobile broadband services cannot be evaluated using the same assumptions for traffic volume. So while the characterization of broadband and the related requirements should not be technology-specific (see response to paragraph 104), it should be service-specific.

In its Report and Order on Preserving the Open Internet, the Commission drew a similar technology-independent distinction between fixed and mobile broadband services, rather than between wired and wireless access technologies, stating that "Fixed broadband Internet access service includes fixed wireless services (including fixed unlicensed wireless services), and fixed satellite services."[13] This distinction is consistent with the significantly different requirements associated with fixed versus mobile services and supports the view that consumers of fixed broadband services should not be hindered by limitations that may be specific to mobile services.

***Connect America Fund NPRM* ¶ 403**

Broadband services must be described in fixed and mobile terms – not wired and wireless terms – because, even after the mobile market becomes saturated by smartphones and tablets, fixed broadband services will require capacity to support traffic volumes an order of magnitude higher than those associated with mobile broadband services. Because of this, one cannot assume that a mobile network can also serve a fixed population, treating fixed users as no more than "mobile users who are stationary." Unless the requirements of fixed broadband service are specifically accounted for at the planning stages, wireless networks attempting to serve fixed broadband populations – even new, higher capacity networks based on LTE or WiMAX – will suffer from extreme congestion and will not meet broadband performance targets or consumer expectations.

B. Broadband Target Speeds and Characteristics

***Connect America Fund NPRM* ¶ 24**

The *Connect America Fund NPRM* seeks comment on "whether the broadband service obligation should be defined as a minimum of 4 megabits per second (Mbps) downstream and 1 Mbps upstream, or whether [the Commission] should use other metrics." While ADTRAN

13 *Preserving the Open Internet; Broadband Industry Practices*, 25 FCC Rcd 17905 (2010), at the definition § 8.11.

believes that the requirement for 4 Mbps downstream is appropriate, 768 kbps rather than 1 Mbps in the uplink direction will allow significantly more efficient utilization of funding and support the provision of broadband service to more consumers at lower cost, without significantly affecting the quality of the service received.

At the same time, ADTRAN notes that without specifying the appropriate parameters in addition to uplink and downlink speeds, these rate thresholds are too ambiguous either (i) to allow comparison of competing performance claims between potential recipients or (ii) to assure that recipients will actually provide broadband service meeting the intended requirements. ADTRAN also notes that data rate-based requirements alone are not sufficient to assure a good quality of experience for widely used consumer broadband applications such as VoIP and interactive video conferencing. ADTRAN addresses these issues in more detail in the comments below.

***Connect America Fund NPRM* ¶ 105**

There are a number of key attributes that should be applicable to any subsidized broadband deployments. The attributes listed below enable broadband services to support widely used classes of applications, including: real time applications such as conversational audio and video; near-real time applications such as streaming video and other media; time sensitive, interactive applications such as online gaming and remote video; transactional applications such as e-commerce and web browsing; and background applications such as email and peer-to-peer file transfer. These attributes have been discussed in detail in a previous *ex parte* submission from ADTRAN and are incorporated by reference herein.[14]

Key broadband attributes include:

- **Downstream and upstream rate targets.** The target rates for broadband access should be 4 Mbps in the downstream direction and 768 kbps in the upstream direction. These rates are sufficient to support the applications classes listed above, while also allowing funding to be applied at the most efficient cost per consumer. Detailed comments supporting these rate thresholds are provided in the response to paragraphs 109-112.
- **Sustained rate.** Performance at or above the target rates should be supported on a sustained basis. That is, performance should support applications that generate traffic at the target rate continuously for periods that may span minutes or hours.
- **Reliable rate.** Performance at or above the target rates should be supported on a reliable basis. That is, the performance should meet or exceed the target rate a high percentage of the time when measured during the busy hour.

Real time interactive and near-real time streaming applications require throughput rates that are both sustained and reliable. Real time interactive applications, in particular, will suffer from severe artifacts (such as freezing or gross distortions in the received video, or loss or garbling of received audio) whenever the data transfer rate drops below the rate required by the application for more than a fraction of a second. Streaming applications are generally more tolerant since they are insensitive to latency and can use receive buffers up to several seconds in length – however, momentary loss of performance that causes the buffer to underrun will cause the streaming playout to freeze while the buffer is refilled. Both of these applications classes require that performance be sustained at or above the data transfer rate with no more than minor exceptions for the full duration of the application session, which can span hours.

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[14] ADTRAN, "Ex Parte Submission: CG Docket No. 09-158," January 6, 2011 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7021025200).

Additional detail is provided regarding sustained and reliable rate performance in the response to paragraph 113.

- **Maximum latency threshold.** The broadband access network should support one-way latency of no more than 50 msec. One-way latency is defined as the network delay (not including variable delay, or jitter) across the access network in either direction.

The maximum latency threshold above is derived from the well known effect of latency on conversational speech (which affects both interactive audio and video conversations) as described in ITU-T Recommendation G.114.[15] G.114 notes that "Although a few applications may be slightly affected by end-to-end (*i.e.*, 'mouth-to-ear' in the case of speech) delays of less than 150 ms, if delays can be kept below this figure, most applications, both speech and non-speech, will experience essentially transparent interactivity."[16] Figure 1 in G.114 provides additional detail, showing that one-way delay above approximately 150-200 ms causes increasing dissatisfaction with conversational speech quality.

The 150 ms value in G.114 is from "mouth to ear," meaning that it includes all elements contributing to the delay between the speaker's mouth and the listener's ear. Some of these elements are outside the scope of the broadband access network. Encoding, framing and decoding delays and dejitter buffering take place in the endpoint devices and typically account for about 50 ms. Propagation and forwarding delays across the Internet can account for up to another 50 ms on intra-continental connections spanning the United States. Finally, most real time interactive applications will span two broadband access networks – one serving the user at

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15 ITU-T, "International telephone connections and circuits – General Recommendations on the transmission quality for an entire international telephone connection," Recommendation G.114, May 2003 (hereafter cited as "G.114").

16 *Id.* at p. 2.

each end of the conversation. If 50 ms maximum delay is allocated to each broadband access network, the maximum mouth to ear one-way latency should remain below the 150-200 ms limit for applications using intra-continental connections.

- **Limitations on usage.** Limitations on allowed traffic volume (if any) should be appropriate for the service being funded. Any explicit or implicit limitations on traffic volume must not affect more than a small minority of the users of a given service.

As noted in the response to paragraph 104, consumers of fixed broadband services generate much higher traffic volumes on average than do consumers of mobile broadband services. This disparity is reflected in traffic volume caps that have been applied or announced by broadband providers. AT&T and Verizon Wireless offer mobile data plans for tablets and laptops that have monthly data caps ranging from 200 Mbytes to 10 Gbytes.[17] With regard to fixed broadband service, AT&T is imposing a 150 Gbyte cap on DSL customers and a 250 Gbyte cap on U-Verse customers starting in May,[18] and Verizon does not currently impose a cap. While 150 Gbyte or 250 Gbyte caps are unlikely to affect any but the heaviest fixed broadband users at current traffic volumes, if caps at mobile data levels were applied to fixed services they would severely limit the usage even of average fixed broadband subscribers. For example, a 2 Gbyte cap would prevent fixed subscribers from streaming even one movie to the home per month (2 hours at 4 Mbps = 3.6 Gbytes per movie).

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17 *See, e.g.*, http://www.wireless.att.com/cell-phone-service/cell-phone-plans/data-connect-plans.jsp, accessed on March 23, 2011; http://www.verizonwireless.com/b2c/mobilebroadband/?page=plans, accessed on March 23, 2011.

18 http://www.att.com/esupport/article.jsp?sid=KB409045&cv=102#fbid=KY1k9Bcin3i, accessed April 6, 2011.

Connect America Fund NPRM ¶¶ 109-112

ADTRAN believes that the proposed target of 4 Mbps download speed is appropriate, but that the goal of providing universal broadband service is better served by a target upload speed of 768 kbps. The target speeds defined for universal broadband service must reflect a balance between two competing criteria. First, do the thresholds provide a sufficient Quality of Experience (QoE) for the classes of applications that the service should enable? And second, do the thresholds support the goal of making broadband services available to the greatest number of people with the most efficient use of subsidy funds? As demonstrated below, both of these criteria are best served by the proposed rate targets.

C. Broadband Quality of Experience (QoE)

In order to support the goal of making broadband access as widely available as possible for a given level of subsidy funding, it is important to match target rates to the requirements for common classes of applications. Rates that are too low can lead to unacceptable performance – however, rates that are specified too high can unnecessarily increase the level of funding required to reach unserved users.

ADTRAN begins by reviewing the performance characteristics of different application classes as shown in the summary from an earlier presentation to the Commission[19] (reproduced below in Table 1). As reflected in this analysis, interactive real time applications and streaming media applications stand out as the classes for which several conditions exist. First, they require sustained and reliable performance meeting or exceeding a minimum threshold rate in order to

[19] ADTRAN, "Ex Parte Submission: CG Docket No. 09-158," January 6, 2011 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7021025200).

perform at all – this as opposed to other applications classes such as web browsing, for which response times may increase but basic functionality is preserved as performance decreases. Second, there is a defined range of rates (consistent with commonly available broadband access rates) over which application and content vendors have designed their products to perform. Third, it is possible to find guidance regarding the QoE resulting from use of the applications at a given rate.

Table 1 – Application performance characteristics

Applications	Rate	Latency	Jitter	Packet/frame loss
VoIP, video conf.	Video rates from 256 kbps to >2 Mbps and increasing • Sustained rate critical, must be very reliable • Burst rate: N/A	Important <150 msec	Important ≤ size of jitter buffer	Tolerates moderate loss (≈1%)
Video (or audio) streaming	Rates from 256 kbps to 4 Mbps and increasing • Sustained rate critical, must be reliable • Burst rate helps with initial buffering	Tolerated	Tolerated	Tolerates moderate loss (≈1%)
Gaming	Secondary to latency in importance Traffic is bursty, average <<1 Mbps	Important As low as possible	As low as possible	As low as possible
Web browsing	Rates (sustained or burst) above ≈5 Mbps have little effect on response time	Can be more important than rate	Tolerated	Tolerated (TCP)
Email	Rates (sustained or burst) have little effect on response time	Tolerated	Tolerated	Tolerated (TCP)
Peer-to-peer	Higher sustained rate improves transfer time Burst rate: N/A	Tolerated	Tolerated	Tolerated (TCP)

As noted in the response to paragraph 105, interactive real time applications require sustained and highly reliable rate performance. This performance is required in both the uplink and downlink directions. Slide 9 in ADTRAN's previous submission[20] includes a summary of the

[20] *Id.*

ranges of rates common in consumer VoIP and video conferencing applications. As shown in Slide 9, rates from 256 kbps to 2 Mbps are typically required to support consumer video conferencing applications.

Several video calling applications which support standard definition video calls include Skype, Google Video Chat, Windows Live Messenger, Logitech Vid HD, Polycom PVX, and LifeSize Desktop. Of these applications, only Skype and Logitech Vid HD provide recommendations regarding network rates required for different levels of call quality. Skype recommends at least 256 kbps for "medium quality video calls" and 512 kbps for "higher quality video calls."[21] Logitech Vid HD specifies 512 kbps for standard definition video calls.[22] Logitech Vid HD also supports HD video calls, as does Cisco ūmi. Logitech Vid HD specifies at least 1 Mbps for HD 720p calls. Cisco ūmi specifies at least 1.5 Mbps for HD calls.[23]

Based on the ranges supported and the call quality guidance provided as shown above, standard definition video conferencing is supported with high QoE at rates of 512 kbps. Higher rates will support higher QoE, including HD video calling in some cases. Note that most video calling applications can independently set the quality in each direction based on the available bandwidth.

Streaming media applications also require that the network support delivery of content at or above the content's playout rate on a sustained and reliable basis. Many applications can deliver content at a number of rates and select the highest rate reliably supported by the network,

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21 Skype version 5.1.0.112, Call Quality Guide in Help menu.

22 http://www.logitech.com/en-us/349/5788?pcid=5787, accessed on April 5, 2011.

23 http://home.cisco.com/en-us/telepresence/umi/what-you-need, accessed on April 5, 2011.

based on a connection test. Figure 1 below (from ADTRAN's earlier presentation[24]) shows the playout rates for a number of streaming downloads, measured in late 2010 over a network connection which reliably supports over 10 Mbps downlink speeds. While those downloads occurred at many different speeds, all were within a range that spanned 280 kbps to 3.8 Mbps. This range includes high quality downloads from Netflix.com and other sources intended to be viewed on large screen video displays. While this range of download speeds can be expected to increase over time (in fact one additional download not included in Slide 11 required a 20.5 Mbps playout rate – but this was "4k" video, encoded at a resolution four times that of HD and meant to exemplify long term future content), it clearly shows that 4 Mbps downlink rates are sufficient to support streaming media at a high QoE.

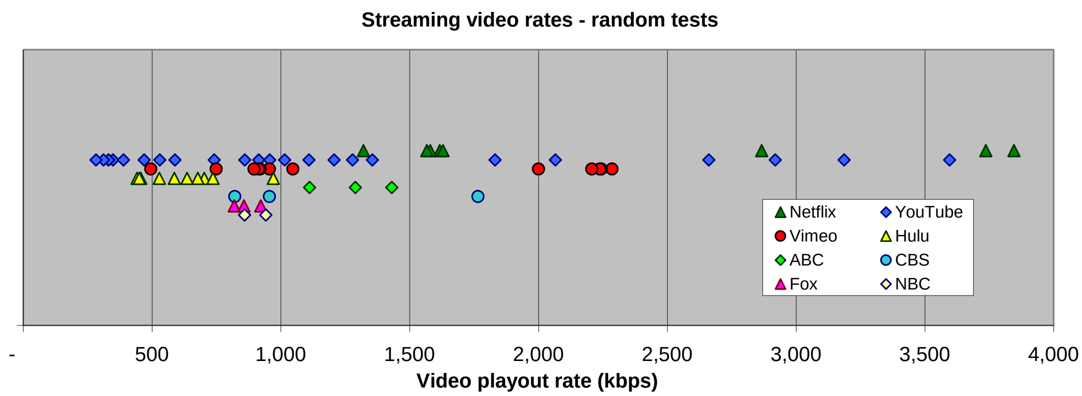

Figure 1 – Streaming video playout rates

Streaming media has highly asymmetric bandwidth requirements, with most traffic generated in the downlink. The primary uplink requirement is for messages acknowledging that downlink traffic has been received (TCP protocol "Acks"). At a downlink rate of 4 Mbps, the uplink requirements are on the order of 100 kbps.

[24] Slide 11 from ADTRAN, "Ex Parte Submission: CG Docket No. 09-158," January 6, 2011 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7021025200).

Other applications classes vary with regard to the effect on QoE of increasing rates, but there are no classes for which threshold rates stand out as they do for the real time interactive and near-real time streaming classes discussed above. Gaming applications generate relatively little traffic, with average rates on the order of 100 kbps or less. Email and peer-to-peer applications vary in the amounts of traffic generated – with peer-to-peer applications frequently transferring very large files – but both classes operate in the background, making file transfer time less important to QoE.

At first glance, web browsing would appear to benefit directly from higher broadband rates. However, most of the time involved in loading an average web page at broadband speeds is spent waiting for responses to messages, rather than actually sending or receiving traffic. Each response – to messages like DNS requests, messages establishing TCP connections and initiating TCP slow start, HTTP Gets, and others – requires a round trip across the network. Hence, above a certain rate, latency becomes a more important factor than rate in determining how fast a web page is delivered.

Web browsing performance can be expressed in the following equation:

$$R \approx \frac{Size}{Bandwidth} + Turns \cdot RTT + Cs + Cc$$

where two factors – *Size/Bandwidth*, the time spent transferring data, and *Turns·RTT*, the time spent waiting for responses – represent the network contribution to web browsing performance (*Cs* and *Cc* are processing time at the server and client ends, respectively).[25] For the following parameters:

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[25] Sevcik, P., and Bartlett, J., "Understanding Web Performance," NetForecast Report 5055, October 2001; Savoia, A., "Web Page Response Time 101," STQE Magazine, Vol. 3, Issue 4, July/August 2001, pp. 48-53. Detailed information on the factors affecting web browsing

- *Bandwidth* = 4 Mbps (the proposed minimum broadband rate),
- *RTT* = 40 msec (a typical round trip time), and
- *Size* = 480 kbytes and *Turns* = 58 (average values from 2009 survey[26]),

we see that *Size/Bandwidth* = 0.96 seconds and *Turns·RTT* = 2.32 seconds, for a total network contribution of 3.28 seconds to the time required to load an average web page.

Increasing the broadband rate can only affect the *Size/Bandwidth* contribution to performance. So, if the broadband rate was doubled from 4 Mbps to 8 Mbps in the above example, the time to load a web page would improve by less than half a second. In fact, if the broadband rate could somehow be made infinite, web browsing performance would improve by less than a second. This shows that increasing rate beyond the proposed broadband threshold of 4 Mbps will not substantially improve the QoE associated with web browsing.

Summarizing the above requirements – in the downlink direction, 4 Mbps enables all of the applications classes, including streaming video with HD quality. In the uplink, threshold requirements are defined by real time interactive applications, where 512 kbps enables SD video and 1.5 Mbps enables HD video (as discussed below, however, such a standard comes at a steep price). We consider these requirements together with the application of subsidy funding below.

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performance, including definition of all terms in the equation, is available in ADTRAN, "Ex Parte Submission: CG Docket No. 09-158," January 6, 2011 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7021025200).

[26] ADTRAN, "Defining Broadband: Network Latency and Application Performance," submission to the FCC in GN Docket No. 09-51, June 23, 2009 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=6520222942).

D. Efficient application of subsidy funding

In March 2010, the National Broadband Plan identified a broadband availability target to guide public funding of "4 Mbps of actual download speed and 1 Mbps of actual upload speed."[27] In April 2010, OBI Technical Paper No. 1 – which described the model used to generate the availability gap identified in the National Broadband Plan – reiterated those threshold values and highlighted Asymmetric Digital Subscriber Loop (ADSL) and Fixed Wireless Access (FWA) as two technologies that meet the requirements for rural broadband deployment with the lowest deployment gap. The paper notes that "DSL over 12 kft loops meets the broadband target of a minimum speed threshold of 4 Mbps downstream and 1 Mbps upstream,"[28] which is true for ASDL2+ performance under controlled conditions at the physical layer. However, conditions in the field can limit performance below that for controlled conditions. In the downlink direction, non-twisted drop wire and in-home wiring is susceptible to Radio Frequency Interference (RFI) from AM radio stations and sources within the customer premises, and bridge taps resulting from unterminated loop plant or in-home wiring can cause nulls in the DSL passband. In the uplink direction, conditions such as repeatered HDSL crosstalk in adjacent copper loops can limit performance.

In addition, most methods for measuring throughput do so at the transport layer – that is, they measure the throughput of a payload encapsulated by TCP and other network protocols. The headers used for these protocols add overhead which reduces the throughput at the transport layer relative to performance at the physical layer. Depending on the network protocols used and

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27 *National Broadband Plan* at p. 135.

28 "The Broadband Availability Gap," OBI Technical Paper No. 1 at p. 85.

other factors such as packet size, overhead can reduce the transport layer throughput by a factor ranging from approximately 7% to 20%. As a result, the measured TCP throughput for a broadband connection providing 1 Mbps at the physical layer can be as low as about 800 kbps.

Broadband performance must be specified in unambiguous terms – for example, to allow accurate evaluation of applications for funding and to allow consistent comparison of proposed, reported and measured performance. Among other things, it is necessary to specify the layer at which speed is defined to prevent ambiguities such as the differing amounts of overhead described above. It makes sense to specify performance at the transport layer (in terms of TCP throughput) for several reasons. First, that definition excludes the different amounts of overhead associated with different access technologies, so it facilitates direct comparison between competing alternatives. Second, any measurement of performance is likely to also be specified in terms of TCP throughput. Third, performance requirements for applications are also likely to be specified in terms of TCP throughput.

When performance is measured at the transport layer under non-ideal deployment conditions on 12 kft loops, ADSL2+'s performance margin is reduced relative to 4 Mbps in the downlink direction and it cannot meet 1 Mbps in the uplink direction. While there are alternatives and mitigation techniques that can be used to meet those target rates (see next section), each carries limitations on feasibility as well as associated costs. As a result, the cost associated with providing universal broadband service at the original proposed uplink rate may be substantially higher than the value arrived at in OBI Technical Paper No. 1. Given that the assumptions used in modeling Fixed Wireless Access (FWA) in the same paper are also invalid and that FWA capacity for fixed broadband services will be only about 20% of the value given in that paper (see comments regarding paragraphs 432-443 for the issues associated with the modeling of FWA), over-specification of broadband target rates could result in a situation where no combination of technologies can provide universal broadband service at a cost anywhere near the originally estimated Broadband Availability Gap.

In the downlink under controlled conditions, ADSL2+ at 12 kft can provide approximately 4.8 to 5.6 Mbps at the transport layer depending on the protocol stack. This range provides enough margin relative to 4 Mbps to cover the large majority of field impairments, meaning that the technology can satisfy both the proposed target rate and the application class requirements from the above section (although protocol stack optimization may be required to minimize overhead in some deployments).

In the uplink direction, ADSL2+ at 12 kft can provide approximately 800 to 970 kbps at the transport layer in the absence of alien crosstalk such as repeatered HDSL. Especially at the high end of the range (achievable with an optimized protocol stack), this performance will satisfy a target rate of 768 kbps in virtually all cases.[29] This target is higher than the 512 kbps required for video calling at standard definition, but below the 1.5 Mbps specified for HD video calling.

Target rates of 4 Mbps downlink and 768 kbps uplink will enable all of the applications classes discussed above, including streaming HD video and interactive video calling with HD in the downlink and SD in the uplink. This combination supports important subclasses of video calling, such as distance learning, where the need for the highest quality video is limited to the downlink. These rates enable single pair, Annex A ADSL2+ to be deployed under the conditions originally modeled for the National Broadband Plan. Compared to the next major step for QoE

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[29] In cables where old 2B1Q HDSL technology is shared with ADSL2+, the HDSL may require upgrading to HDSL4 to ensure 4 Mbps down and 768 kbps up. HDSL4 has been widely deployed and is much more spectrally compatible with ADSL than the older technology.

(video calling with HD uplink), which would require 1.5 Mbps in the uplink, these rates allow broadband to be deployed at a substantially better cost per subscriber that will allow for more efficient use of limited subsidy funds. Additionally, the rates can be specified at the transport layer as TCP throughput rates, excluding protocol overheads which vary between technologies and deployments and allowing direct comparison of performance across competing proposals, as well as allowing direct comparison of rate targets with measured results.

E. Alternatives to changing proposed target rates

The following alternatives are considered to allow ADSL2+ to support the originally proposed target rates, measured at the transport layer:

- **Two-pair bonding.** ADSL2+ supports bonding of multiple loops, which for two loops effectively doubles the rate delivered to the customer. However, this is only feasible if the extra copper loops are available to the customer premises, which may or may not be the case for a specific deployment. Even when the extra loops are available, two-pair bonding doubles the number of ports required in the DSLAM to serve a customer, and it requires equipment that supports bonding both in the DSLAM and in the customer premises modem. These factors virtually double the DSLAM cost and significantly raise the cost for a bonded CPE modem compared to a single loop solution.
- **Annex M operation.** ITU-T Recommendation G.992.5 Annex M specifies ADSL2+ operation with extended bandwidth in the uplink direction. Use of this annex, with sufficient upstream bandwidth, would support 1 Mbps in the uplink to 12 kft – however, it would do so at a high cost to downlink performance.

  The copper loop as a transmission channel changes rapidly over frequency – higher frequencies are attenuated faster than lower frequencies. Annex A ADSL2+ transmission (which is normally deployed over POTS in the US) allocates frequencies from 25 to 138 kHz to the uplink and from 138 kHz to 2.2 MHz to the downlink. At 12 kft, most of the information capacity in the downlink channel is in the lowest frequencies of the downlink band.

  Annex M works by increasing the frequency that divides uplink and downlink transmission from 138 kHz to as much as 276 kHz – in essence, stealing bandwidth from the downlink channel to give it to the uplink channel. However, since higher frequencies on the loop are attenuated faster than lower frequencies, the new bandwidth being added to the uplink channel cannot carry as much information per Hz as the bandwidth already allocated to that channel. For the same reason, the bandwidth being removed from the downlink channel carries more information per Hz than the remaining downlink bandwidth. As a result, any addition to uplink capacity carries a disproportionally high cost for downlink capacity.

Preliminary checks indicate that it may be possible to achieve a balance resulting in 4 Mbps downlink and 1 Mbps uplink at the transport layer by moving the crossover frequency from 138 kHz to approximately 224 kHz. However, this does not take interference from HDSL or other field impairments into account, and it does not allow mixing Annex M and Annex A systems in the loop plant.

There is also a performance cost to the user associated with Annex M. Over 1 Mbps in downlink performance would be sacrificed in Annex M systems in order to increase uplink performance by less than 250 kbps. Given the prevalence of streaming video and other applications classes with highly asymmetric bandwidth needs, such a tradeoff would be ill advised. Finally, even if the other issues did not exist, there are costs involved in purchasing, inventory, deployment and management of Annex M that would increase required subsidy funding levels.

- **Engineer for shorter loops.** Another alternative is to engineer the loop plant such that the longest loop used supports the 1 Mbps at the transport layer. This alternative, of course, invalidates the loop plant design assumptions made during modeling for the National Broadband Plan and virtually guarantees that actual costs will exceed the modeled availability gap. Depending on the hardware and protocol implementation, this approach would shorten the maximum loop length supported from 12 kft to as little as 8 kft. Serving areas based on 8 kft loops would require over twice as many distributed DSLAMs to cover the same geographic area as serving areas based on 12 kft, with corresponding increases in installation and maintenance costs and fiber backhaul deployment.

While some of the alternatives discussed above may be appropriate for specific situations, all are significantly more expensive to deploy than single pair, Annex A ADSL2+. Based on the above analysis, we believe the goals of the National Broadband Plan are best served with target rates of 4 Mbps downlink and 768 kbps uplink, rather than by setting arbitrary targets that force higher cost solutions without significant corresponding benefit to the consumer.

***Connect America Fund NPRM* ¶ 113**

The following characteristics are critical to an unambiguous and meaningful definition of "actual" speed:

- First – in order for a definition of rate to be unambiguous, one must define the specific bits of data to which the term applies. When different technical communities discuss data transmission rate (or speed), they mean the number of bits of data transmitted per time interval – however, depending on the community, bits which are inserted or extracted at different layers in the protocol stack may not be included. For instance, it is common in the DSL community to refer to the number of bits per second transmitted at the physical layer across the subscriber loop. In contrast, most rate measurement methodologies (including the one used by SamKnows as referenced in the *Connect America Fund NPRM* at ¶ 115) measure the successful transmission of payload data over TCP, or TCP throughput. Depending on the broadband access technology and the protocol stack used, the rate as defined by TCP throughput can be up to 20% lower than that defined at the physical layer.

  ADTRAN proposes defining the TCP throughput as the numerator in the rate equation (rate = data/time) – that is, the number of bits transferred in the TCP payload. In addition to being consistent with most common measurement techniques, this eliminates technology-specific variations in interpretation of the definition.

- Second - as discussed in the responses to paragraphs 105 and 109-112, it is critical for interactive real time applications and for near-real time streaming media applications that broadband performance be sustainable over time periods of minutes to hours. Some broadband access technologies provide dual levels of performance – an initial "boosted" level exceeding the stated terms of service which may last for several seconds at the beginning of a transaction, and a lower level limited by the terms of service which can be sustained (in the absence of network congestion) for extended periods. While the momentary "boosted" rate adds incremental value to certain types of transactions, only the sustained rate can be applied to the target rates required for interactive real time voice/video and streaming media.

- Third - as discussed in the responses to paragraphs 105 and 109-112, it is critical for interactive real time applications and for near-real time streaming media applications that broadband performance be reliable. In the context of defining "actual" speed, one way to address reliability is to specify the percentile value at which the broadband connection must meet or exceed the target rate when measured. For instance, a broadband connection that meets a target rate at the 95th percentile level will perform at or above the target rate 95 out of 100 times when measured. Specifying rate at a higher percentile implies more reliability than a lower percentile, for example in that a connection that performs at or above 4 Mbps 95% of the time can be considered more reliable, relative to the target rate, than a connection that performs at or above 4 Mbps only 50% of the time.

- Fourth – it is important that the definition of actual broadband performance emphasize the performance achievable when the network is loaded the most heavily – that is, at the busy hour – rather than simply averaged over a 24 hour period or reported relative to a time when the network is lightly loaded. The diurnal patterns associated with broadband usage are well documented,[30] with most consumer usage occurring during the evening hours and most business usage occurring during daytime business hours. Since more users are accessing broadband services at the busy hour than at any other time, the performance during that period affects more users than performance experienced at other times. Additionally, the heavier load placed on the network during the busy hour tests network performance to a greater degree than at other times of the day.

Rather than propose specific percentiles for reliability or times for busy hour, we defer to the work of the broadband performance measurement project described in the discussion related to paragraph 115, below. The participants in that project are working to define terms together with the test methodologies under which performance is measured.

F. Broadband Measurement

***Connect America Fund NPRM* ¶ 115**

Since early 2010, the Commission has been working with industry, academia and other groups on a project to measure broadband performance in a consistent and meaningful manner. ADTRAN supports this effort and believes that elements of it should be applied as appropriate to the characterization of broadband for purposes of universal service funding. For example, project participants are currently working to determine the best way to characterize actual performance – whether it should be on the basis of one or more percentile levels, or average performance, or how to characterize busy hour performance as compared to a 24 hour average. Using the appropriate parameters and methodologies generated by the project across USF/CAF and other broadband initiatives will leverage the considerable efforts that have already gone into that project, promote consistency and minimize confusion for both the FCC and industry.

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30 Thompson, K., Miller, G., Wilder, R., "Wide Area Internet Traffic Patterns and Characteristics," IEEE Network, November/December 1997.

***Connect America Fund NPRM* ¶ 116**

Without commenting on the specific mechanism that should be used, we note that performance measurement post deployment has several benefits. In addition to the obvious benefit of verifying actual broadband performance as opposed to estimates made prior to deployment, testing can be used to monitor actual versus projected traffic volume. Since future actual traffic volume is certain to deviate to some degree from current projections, such monitoring can allow fine tuning of support levels as well as increasing the accuracy of ongoing projections.

Whatever mechanism is put into place to measure broadband performance should occur on a periodic basis. Broadband performance will vary over time as additional subscribers in an area sign up for service and as per-subscriber usage increases, and periodic measurements can verify that performance expectations are being met throughout the agreed period of service.

***Connect America Fund NPRM* ¶ 117**

Figure 4 in the ***Connect America Fund NPRM*** has appeared in previous FCC documents and has been used within the Commission's broadband performance measurement project described in the discussion of paragraph 115, above. In fact, the question of what endpoints should be used in measuring broadband performance was one of the first topics addressed by the Commission and its partners in that project.

At the customer premises, the endpoint used for any definition or measurement of broadband performance must be as close as possible to the demarcation between the broadband service provider and the customer, identified in Figure 4 as Point 5. Ideally, the customer's home network and devices should be excluded completely from the definition. While many broadband providers provide consumer education on home networks in the form of online FAQs and other technical support, the broadband provider has no control over nor knowledge of the customer's home network configuration or topology beyond the point of demarcation and cannot be responsible for performance problems caused by that part of the transmission path.

Defining the network endpoint is more problematic, because there is no clearly defined demarcation as there is at the customer site. While the Internet gateway (shown as Point 2) is a logical proposal in theory, it presents a number of issues in practice. For example, a broadband service provider may have a number of physical interfaces at different locations interfacing to other operators' networks, all of which could be considered "Internet gateways," and all of which might be used by the same subscribers when accessing different content or applications. Using all of those sites as measurement endpoints raises issues of cost (installation and maintenance of test servers at each site) and definition (how should the results associated with each site be combined?). Using one or a subset of sites begs the question of how representative those sites are compared to the network as a whole. Additionally, measurement at Point 2 may not reflect performance improvements due to caching or content delivery networks, creating a disincentive to using those techniques in funded deployments.

Another issue with Point 2 is that different network providers have different architectures and scopes of control. While a national provider may carry traffic from rural areas to large peering sites to achieve benefits of scale, a regional provider with a smaller geographic footprint may not have the same option, instead handing traffic off within their footprint to a transport provider. In such cases, there is no clear cut, consistent definition for Point 2. If defined as the interface between the broadband service provider and another provider, then transport elements may be included for the national provider but not the regional provider. If defined only at large peering points, then transport elements outside the regional provider's direct control may be included.

While there is no ideal definition of Point 2, it is still better than the other points shown on the diagram in that it comes closest to representing the scope of the network controlled by the broadband service provider. Again, ADTRAN defers to the work that has been done within the broadband performance measurement project. The participants have expended considerable effort to arrive at a workable set of network test points approximating Point 2, and a number of broadband providers have installed test servers at corresponding sites. Revisiting this question will not necessarily generate a better answer – however, if it leads to a different result, it could lead to inconsistent measurement results or invalidation of the work already done. ADTRAN thus recommends that the work done by the current project be used as guidance for future funded deployments.

***Connect America Fund NPRM* ¶ 118**

ADTRAN concurs that end-to-end speed tests have drawbacks which prevent their effective use in measuring the performance of broadband services. Such tests include network elements (both at the customer premises and across the Internet connecting to the test servers) which are outside the scope of the broadband provider's network or control.

G. Subscriber Coverage

***Connect America Fund NPRM* ¶¶ 129-131**

Without commenting specifically on whether or not the Commission should adopt a coverage requirement, we note that the term "coverage" needs to be defined for the purpose of funding services. Specifically, for a housing unit or other entity to be included in the pool of covered potential subscribers, there must be a reasonable expectation that the service provider can provide broadband service to that specific entity – not just in the average for the population including that entity – at the target rates and other characteristics associated with the funded deployment.

All broadband access technologies have limitations regarding the distances from the serving equipment to which they can provide service. The ease with which these limitations can be analyzed ranges from straightforward to multidimensional and complex:

- Fiber-based Active Ethernet can be assessed against a straightforward attenuation budget, accounting for distance, splices and other connections.
- GPON can be assessed similar to Active Ethernet, with the addition of optical splitters. The technology must also be assessed to make sure it provides enough shared capacity for the pool of users served by each node. (See the comments below regarding modeling for additional detail on capacity and performance.)
- DSL requires determination of both signal attenuation (dependent on loop length, gauge, and configuration) and crosstalk from interfering sources in the loop plant.
- HFC networks using DOCSIS can be assessed against amplifier noise, upstream noise funneling, and shared capacity.
- Wireless access networks are considerably more difficult to assess than those based on the other technologies listed above. Wireless reception varies based on distance and terrain and is also subject to temporal effects such as fading. As with other shared capacity technologies, wireless capacity must be assessed against the pool of subscribers – but that pool is variable, with mobile users entering and exiting cells at random times. The fact that mobile and fixed broadband users are likely to share a wireless network offering fixed broadband service further complicates analysis. Finally, many of the

algorithms which directly affect performance for individual subscribers – such as MIMO, beamforming and scheduling – are optional and/or proprietary. For example, the schedulers that allocate radio resources in wireless cells can use any algorithm and be optimized for any of a number of parameters, such as total cell capacity or coverage. However, commonly used algorithms such as proportional scheduling increase overall cell capacity at the expense of performance for the users furthest away from the base station.

Applicants for subsidy funding should show that subscribers located at the limit of the coverage area – regardless of how that area is defined – can receive broadband meeting the service's requirements. This includes, for example, subscribers on the longest loops included in the served population, or subscribers located at the cell edge for wireless access. Entities who cannot receive service at the stated requirements should be excluded from the covered population.

H. Modeling

***Connect America Fund NPRM* ¶¶ 405, 432-443**

ADTRAN supports the use of a model to estimate levels of required support for broadband services, so long as the model is transparent, well designed and reviewed, and so long as reasonable projections and assumptions are used in execution of the modeled scenarios. With regard to the model used in estimating the broadband availability gap for the National Broadband Plan,[31] ADTRAN has noted in a number of previous submissions to the Commission that, while we believe the OBI model provides a good basis for modeling support levels, a number of issues with the model and its input parameters require correction in any future application.[32]

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31 "The Broadband Availability Gap," OBI Technical Paper No. 1.

32 ADTRAN, "Ex Parte Submission: GN Docket No. 09-51 -- OBI Technical Paper 1," May 28, 2010 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7020503385); ADTRAN, "Comments of ADTRAN, Inc.," July 12, 2010 (available at

Specifically:

- The estimate of 160 kbps for Busy Hour Offered Load (BHOL) used for network dimensioning throughout the model underestimates BHOL by a factor of almost three. The artificially low estimate results from taking a reasonable projection for BHOL in the year 2014 (of about 444 kbps) and excluding the contribution of the top 10% of heaviest users. In addition to contradicting the stated purpose of providing universal service, the exclusion relies on unrealistically aggressive assumptions about the capabilities of network traffic management and policy elements, and then fails to accurately model the resulting distribution of traffic should such elements be capable of providing such idealized truncation.
- The capacity estimate of 650 fixed users per cell used for FWA modeling is unrealistically high. This is true even if the original input parameters from the model (including 160 kbps for BHOL) are used to generate the estimate, which would require an *average* (not peak) utilization of 114%.
- The model assumes paired 20 MHz channels in the 700 MHz band for its baseline analysis. This is at odds with the actual allocation of that band, which is split into blocks of 12 MHz or less.

The cumulative magnitude of the potential error introduced by these issues is significant – if they are all corrected, the resulting estimated capacity for 40 MHz of wireless spectrum (including cumulative uplink and downlink bands) falls from the original estimate of 650 fixed broadband users (and 1300 mobile users) to only 100-120 fixed broadband users and 200-240 mobile users. ADTRAN also notes that the corrected estimate is based on an optimistic model that combines the average spectral efficiency for a wireless sector estimated based on proportional scheduling, with analysis based on max-min fairness scheduling that is likely to result in significantly worse average spectral efficiency – so in fact, the actual capacity may be even lower than that estimated here.

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http://fjallfoss.fcc.gov/ecfs/document/view?id=7020522295). We incorporate the text from these earlier submissions into these comments by reference to provide detail in support of the above points.

As noted by one of the issues raised regarding the estimates documented in OBI Technical Paper No. 1, no model can be better than the input data provided to it. In the case of the OBI model, flawed input values for BHOL and other factors led to estimates that significantly overstated the capacity potential capacity of a wireless cell. One of the fundamental requirements for any model going forward is the generation of reasonable and transparent input data. In the case of BHOL, this data can be projected from actual usage data provided by service providers and from the Commission's broadband measurement project, combined with projections available from Cisco, ADTRAN and other sources. Regardless of the sources, input parameters should be subject to the same review process used by the rest of the model.

I. Application-stage estimation of performance

Applications for funding should include evidence that planned networks will support the required performance targets through the agreed period of performance, given projected traffic volumes for the service. Evidence could be in the form of transparent/reproducible simulation results or closed form analysis. Examples of the types of simulations or closed form analysis that could be used are provided below.

Because performance is strongly dependent on traffic volume as well as the number of users, the Commission should determine (with input from industry and academia) reasonable parameters, including BHOL projections, to use as inputs for performance estimates.

J. Simplified models

ADTRAN has previously submitted information describing a Monte Carlo simulation model that estimates the range of expected performance based on network capacity, traffic loading and other factors.[33] ADTRAN incorporates that submission by reference as well, as an example of a relatively simple mechanism for estimating performance of a network utilizing shared bandwidth among a pool of users. The scope of the model is much smaller than that of the OBI technical model, dealing only with performance estimation within the access network. However, it may be useful as a cross check for other methods.

For simple deployment scenarios in which network capacity is shared among a pool of subscribers in a single performance tier, there are closed form methods for generating a first pass estimate of required capacity based on the number of subscribers served, the average BHOL generated by those subscribers, and the required performance. An example is shown below, in which a linear approximation has been fit to the Monte Carlo simulation results generated by the following input parameters for increasing numbers of subscribers:

- Average BHOL = 500 kbps
- Target rate = 4 Mbps
- Percentile at which target rate is defined = 95%

The equation approximating the capacity required for the above parameters is

$$Capacity \geq \begin{cases} 0.56U + 9, U \leq 138 \\ 0.625U, U > 138 \end{cases} \text{, where}$$

Capacity = capacity (in Mbps) of the node to serve downstream users, and
U = number of users served by the node.

The linear approximation has two segments. At high numbers of subscribers, the statistical multiplexing provided by the packet network is such that average utilization predicted by the simulation could begin to exceed 80% - however, we limit the utilization to that value on the assumption that network design guidelines would include a similar limitation. This is reflected

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33 ADTRAN, "ADTRAN Inc., Submission in WC Docket No. 10-90, GN Docket No. 09-51 and WC Docket No. 05-337," August 5, 2010 (available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7020659403).

in the second line of the capacity equation and in the right hand portion of Figure 2, where the number of subscribers exceeds 138.

As the number of subscribers decreases, statistical multiplexing becomes less efficient such that the average utilization that can be supported decreases. This is reflected in the first line of the capacity equation and in the left hand portion of Figure 2.

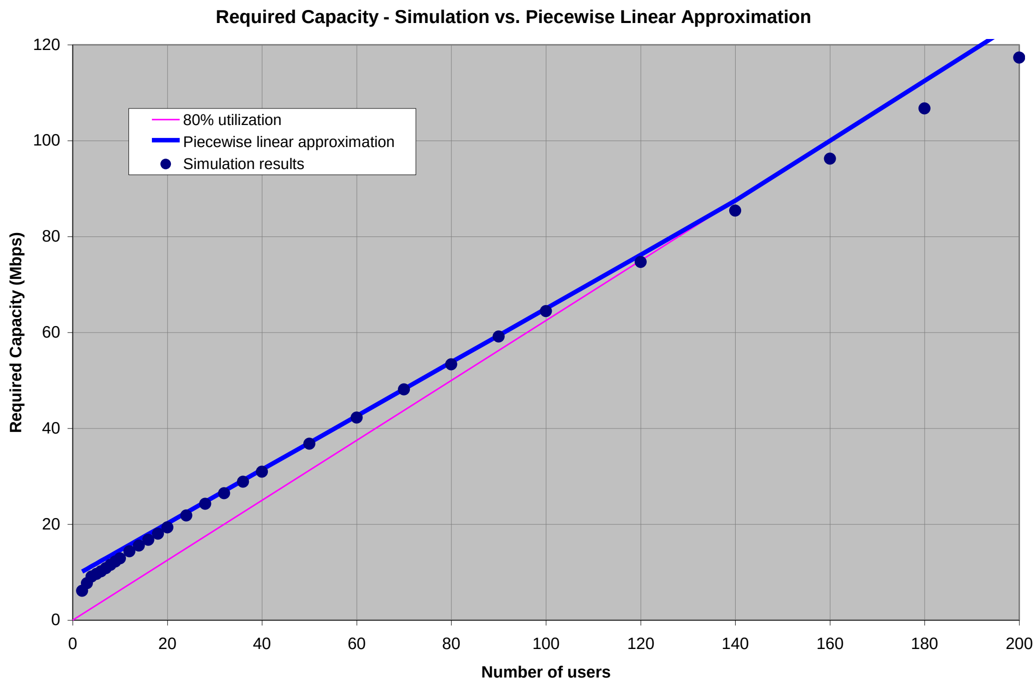

Figure 2 – Closed form capacity estimation example

A simple closed form solution of the type shown above is difficult to extend to more complicated deployment scenarios, such as those incorporating more than one performance tier or multiple types of users with different plans and/or usage characteristics (such as fixed and mobile broadband subscribers sharing a common wireless network). For those scenarios, simulation may be required to demonstrate sufficient network capacity.

III. CONCLUSION

ADTRAN supports the Commission's proposals to reform the current USF subsidy program and intercarrier compensation rules in order to support the deployment of advanced broadband capabilities to unserved areas. The current systems, based on circuit-switched voice services and originally developed in an era of monopolies, must be adapted to the 21st Century. ADTRAN believes the public interest will best be served if the Commission does so in a technology neutral, efficient and forward looking manner as suggested herein.

Respectfully submitted,

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